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(54) IMPROVEMENTS IN OR RELATING TO BUOYANCY REGULATION

(71) I, DONALD GEOFFREY POPE, a British subject of Golden Gleam, Lilley Bottom, Luton, Bedfordshire, LU2 8NH, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:

The invention relates to apparatus for regulating buoyancy of an underwater diver in relation to ambient pressure in the water. The invention is of particular applicability to divers wearing wet suits, and utilises novel control means to pass gas into and out of a chamber of variable volume thus to vary displacement of the chamber in the fluid.

As is well-known, the development of self-contained underwater breathing apparatus has promoted an enormous increase in the amount and variety of diving activity, both professionally and for pleasure. The extent of such activity is, in essence, limited by human constrains; by interlinked physical, physiological and psychological effects, such as the way in which increasing depth increases both physical and psychological stresses upon the diver and hence increases his rate of consumption of the breathing medium. It follows that the scope and safety of a dive can each be increased by easing the demands placed upon the diver, and this the present invention seeks to do.

One of the most significant problems faced by a suited diver is how to maintain a desired buoyancy, whether positive, negative or neutral. It will be appreciated that to descend unaided the diver requires negative buoyancy. However, as the diver descends the gas necessarily entrained in the suit will be compressed, owing to increasing pressure with depth. The compression of the entrained gas reduces the buoyancy; that is, negative buoyancy will increase with depth so that a diver who is weighted for negative buoyancy at the surface will, in the absence of effort, continue to descend to the bottom. For this reason underwater divers generally weight themselves with calculated positive buoyancy at the surface and swim down to their desired operating level at which, owing to compression of the wet suit they are substantially neutrally buoyant. If a diver swims below his calculated operating depth he begins to develop negative buoyancy, which, as previously stated, increases with depth. Thus some effort must be wasted for the diver to reach his operating depth and also there is the hazard that if the diver becomes unconscious for some reason whilst in a state of neutral or negative buoyancy, it will require the release of some weight to take him unaided back to the surface.

The problems of controlled ascent of divers, which are also compounded by buoyancy changes, are well-known. If a diver is to avoid decompression sickness it is generally considered essential that he should rise to the surface at a rate not much greater than 18 metres/minute. Thus some automatic control of the diver's rate of ascent is desirable.

Besides the compression of the wet suit with depth, the buoyancy of a diver also depends upon time as his highly compressed breathing medium is consumed. For instance, there may be 2 kg. of air lost from air cylinders between their fully-charged state and the safe end of a dive, when about 0.5 kg. of air remain. A diver can, to some extent, control his buoyancy by controlling his respiration to achieve about ±1 kg variation in buoyancy, but this is insufficient for effective regulation of his buoyancy.

It is a particular feature of the present invention that, by its use, a diver's buoyancy may be maintained at a desired value, be it negative for an easy descent, neutral for a desired operational depth or for decompression stops, or positive for a controlled ascent. Thus, whilst the invention may well have

other applications, it is especially intended to enable a diver's buoyancy to be regulated, thus to ease the demands placed upon the diver and allow him to dive more safely and efficiently.

According to the invention there is provided apparatus for regulating buoyancy of an underwater diver in relation to ambient pressure in the water and comprising a supply of gas at a pressure which in use is above the maximum ambient pressure, a resilient chamber, for gas, of volume variable (at constant ambient pressure) linearly with pressure int he chamber and control means for controlling the volume of gas within the chamber thus to vary its displacement in the water, wherein the control means comprises:

a housing having a first port connected to said supply of gas, a second port connected to said chamber and a third port open to the water;

valve means arranged within the housing to cooperate with said ports, which valve means has a null position wherein all the ports are shut off from one another by the valve means, a first position wherein the first and second ports are in communication, and a second position wherein the second and third ports are in communication;

a transducer within the housing, which transducer is responsive to ambient pressure and operative to move the valve means from the null position to the first position when the ambient pressure increases and from the null position to the second position when ambient pressure decreases;

and spring means to urge the valve means towards the null position.

It will be noted that, since variations in ambient pressure will be dependent almost solely upon depth from the surface, the apparatus will enable compensation of depth-dependent changes in the diver's buoyancy, and notably the aforementioned changes due to suit compression.

It is preferred that the control means be manually adjustable to set the buoyancy of the apparatus to a desired amount.

The chamber may comprise a piston and cylinder arrangement or, preferably, a resiliently deformable bag, which may include a number of compartments. The chamber may also be arranged to function as a lifejacket and preferably includes means whereby it may be manually emptied and/or filled. The means for securing the apparatus to the body may itself include the chamber.

The invention will now be described by way of example with reference to the accompanying drawings in which:-

Figure 1 is a graphical representation of the effect of dive depth upon buoyancy;

Figure 2 is a schematic representation of apparatus, according to the invention, for regulating buoyancy of an underwater diver;

Figure 3 is a sectional representation, to an enlarged scale, of control means of the apparatus of Figure 2;

Figure 4 is a sectional representation of a coupling and valve arrangement of the control means of Figure 3;

Figure 5 illustrates the transient response of the control means of Figure 3 to an increase of ambient pressure;

Figure 6 illustrates the transient response of the control means of Figur 3 to a decrease of ambient pressure;

Figure 7 is a sectional representation of an alternative form of control means of the apparatus of Figure 2; and

Figure 8 is a sectional representation of part of another form of control means of the apparatus of Figure 2.

As is well-known, the volume of a fixed quantity of gas varies inversely with pressure. Thus, if the gas is displacing another fluid, its buoyancy in that other fluid similarly varies inversely with pressure. A suit of an underwater diver will necessarily have a substantially fixed quantity of gas entrained therein and this quantity of gas will be progressively compressed as the diver descends in the water. It follows that the buoyancy of the entrained quantity of gas will correspondingly reduce as the diver descends, and Figure 1 illustrates this effect.

In Figure 1 the abcissa represents the dive depth and is calibrated in metres. The ordinate represents buoyancy as a percentage of its value at the surface. Curve 10 characterises the behaviour of a fixed quantity of gas at constant temperature, considered isolation. The progressive reduction of buoyancy with increasing depth will be noted, and in particular the comparatively rapid change near the surface; the gas loses approximately half its initial buoyancy in the first 10 m. If the gas, rather than being isolated, is entrained, its behaviour is naturally modified by the entraining medium. Curve 12 characterises the behaviour of neoprene, such as is used for wet suits and which entrains some gas. Curve 12 drops below curve 10, although the difference is negligible at depths of less than about 20m. It will be seen that the buoyancy of the neoprene at a depth of 50m. is only about 10% of its buoyancy at the surface, and thus a wet suit-clad diver may easily reach a depth where he has negative buoyancy. Such negative buoyancy can of course be of danger to a tired or sick diver. It will also be appreciated that the increasing buoyancy afforded an ascending diver will tend to accelerate his ascent, with the consequent risk of decompression sickness.

Figure 2 depicts apparatus intended to overcome these problems by regulating the buoyancy of the diver. A tank 14 of the

diver's self-contained underwater breathing apparatus is open by way of a line 16 to the high-pressure side of a demand valve, indicated at 18. The tank 14 contains air, or some other breathing medium such as a mixture of helium and oxygen, which is fed from the low-pressure side of the demand valve 18 to the diver's mouthpiece, not shown, by way of line 20. A line 22 leads from the low-pressure side of the demand valve 18, by way of a quick-release coupling indicated at 24, to control means 26. The control means 26 includes a pressure transducer 28 and a two-way, three-position valve 30, operatively associated with the transducer 28. The valve 30 has a first port open to line 22 by way of the quick-release coupling 24, a second port open to a line 32 and a third port open to a vent 34. The line 32 leads to the chamber of a cylinder 36 wherein pressure acts on one side of a piston 38, the other side of which is subject to ambient pressure and the reaction of compression spring 40.

Figure 2 shows the valve 30 in a central, null position. The action of the transducer 28 is such that, when subject to increased ambient pressure, it moves the valve 30 leftwards to interconnect the first and second ports, and thus cause high-pressure air to be delivered to the chamber of the cylinder 36. The pressure of this air, which is typically about 100 lbf/in.^{2} above the ambient pressure, drives the piston 38 outwards against the ambient pressure and the force of the spring 40. Thus the displacement of the chamber, and hence its buoyancy, is increased. Conversely, if there is a reduction in ambient pressure, the valve means 30 is moved to the right to interconnect its second and third ports, and thus open the chamber to the vent 34. The spring 40 then resites to effect a closing movement of the piston 38 and a corresponding reduction in buoyancy of the chamber results.

The transducer 28 is in fact arranged to be responsive to the opposed actions of the ambient pressure (assisted by the spring 40) and the pressure in the chamber of the cylinder 36. Thus, when these two pressures are equal, the valve 28 is in its null position. In this way there is provided control means operative to regulate buoyancy. The apparatus of Figure 2 is secured to the diver's body by means such as a harness of known form, and thus the diver's buoyancy is regulated.

Of course, like that of other diving equipment, this harness should have a quick-release facility to enable the apparatus to be jettisoned rapidly if necessary, and this is the reason for the quick-release coupling 24 in the line 22. It should also be pointed out that the form and disposition of the line 22 and coupling 24 can be varied as convenient: it is not essential for the pressurised gas to be fed from the demand valve, although this offers gas at a pressure which is high enough to be effective without being, as is the gas in the tank 14, excessive for use in this apparatus.

The piston and cylinder arrangement shown in Figure 2 is also not essential. An alternative, and possibly more convenient, chamber comprises a resiliently deformable bag including one or more compartments arranged to expand and contract progressively, thus to vary displacement and buoyancy with depth in such a way as to compensate as closely as possible, for the buoyancy changes indicated by curve 12 of Figure 1. Such a bag may be included in the harness of the apparatus and arranged also to function as a lifejacket. To this end the bag should also be arranged to be filled independently of the operation of the apparatus, for instance by mouth, and there should also be provision for rapid emptying of the bag so that the diver shall not be prevented from descending if need be.

Whatever form of chamber is selected, it must naturally be arranged so that its buoyancy will not have an adverse effect upon the diver's attitude in the water, either submerged or at the surface. Also, of course, it must have a sufficient range of displacement to cover the range of buoyancy to be regulated.

The integers and operation of the invention having now been outlined, the control means of the apparatus will now be described in more detail, with particular reference to Figures 3 to 6. Referring firstly to Figure 3, this shows the control means to have a housing 42 formed at one end with lugs 44 to receive a harness strap. Screw-threadedly received on the other end of the housing 42 is an end cap 46 which carries at its centre a stud 48.

The stud 48 is arranged for rotational movement relative to the end cap 46 and is secured to one side 50*a* of an air-filled capsule 50. The other side 50*b* of the capsule 50 bears against the enlarged stem-ends 52*a* of two valves 52, which valves are carried by and seat around ports 54*a* in a slider 54. Each valve 52 is biased from the slider 54 by a spring 52*b*, to the left as seen in Figure 3. The slider 54, which has piston-like engagement with the housing 42 by means of a seal 56, is biased to the right by a spring 58.

Extending from and secured to said other side 50*b* of the capsule 50 is a shaft 60 which extends through a sealed bearing 62 in the centre of the slider 54. A link 64 connects the free end of the shaft 60 to an arm 66 which is pivotally connected to the slider 54 by a pivot 68. The arm 66 is so arranged that its pivotal movement causes it to bear against a trigger 70 of a coupling and valve arrangement shown in Figure 4. The valve part of this arrangement is of substantially the same

form as the tilt valve mechanism commonly used in demand valves of self-contained underwater breathing apparatus, and thus it is considered that no fully detailed description is required. In essence the valve comprises a case 72 formed with a seat 74 against which a seal 76 is held by gas pressure in the case 72. The seal 76 is carried at the end of the trigger 70, the arrangement being such that tilting of the trigger 70 will lift the seal 76 from the seat 74 and thus effect the release of gas by the valve. The rate of release of gas will be understood to be dependent upon the degree of tilt of the trigger 70.

The case 72 is formed with a bayonet fitting and connector, indicated at 78, whereby a one-way connexion is made to a supply of gas at about 100 lbf/in^2 above ambient pressure, which supply may conveniently be a suitably throttled supply from the tank of the diver's breathing apparatus. (The connexion is such that, when disconnected, the supply is sealed.) In this way, as will be described in more detail hereinafter, pressurised gas may be delivered into the space 80 within the housing 42 which is closed off by the slider 54. A port 82 is open between the space 80 and a resiliently deformable variable displacement bag, not shown. The remaining space 84 within the housing 42 is open to the water (and hence to ambient pressure) by way of vents 86 in the end cap 46.

Figure 3 shows the control means in a null state such as would be its setting before the diver enters the water. As the diver descends in the water there will be an increase in ambient pressure, the effect of which is shown, exaggerated for clarity, in Figure 5.

In Figure 5, the increased ambient pressure in the space 84 has compressed the capsule 50, and also the gas in space 80, thus causing the side 50*b* of capsule 50 to move away from the slider 54. The consequent movement of the shaft 60 in the bearing 62 has caused the arm 66 to pivot and actuate the trigger 70. Thus pressurised gas is being delivered to the space 80 and hence, by way of the port 82, to the variable displacement bag. In this way the bag is inflated to increase its buoyancy.

At all depths the gas pressure will be about 100 lbf/in.^{2} greater than the ambient pressure, and accordingly the delivery of the pressurised gas to the space 80 will drive the slider 54 towards the left against the combined forces of the ambient pressure and the spring 58. It follows that, as depicted in Figure 5, the slider 54 will be moving towards the side 50*b* of the capsule 50, thus to restore the control means to a null state wherein the trigger 70 is inoperative and the pressure in the space 80 is balanced by the ambient pressure and the spring 58. The control means thereby provides control of the inflation of the variable displacement bag so that the diver's buoyancy is regulated in a predetermined direct relationship to the ambient pressure. In other words, for all practical purposes, his buoyancy is regulatedly increased with increasing depth.

Figure 6 shown, again exaggerated, the transient response during ascent. As represented in Figure 6, the diver has ascended from some depth at which the ambient pressure has compressed the capsule 50 to bring its sides 50*a* and 50*b* comparatively close together. The ascent to a region of lower ambient pressure has caused the pressure in the space 80 to drive the slider leftwards, closer to the side 50*b*, and an expansion of the capsule 50, resulting in a relative closing movement of side 50*b* and slider 54 which has caused the valves 52 to be lifted off their seats against the light force of the springs 52*b*. Gas in the space 80 can thus escape through the ports 54*a* and vents 86. The variable displacement bag will accordingly be deflated to a state of reduced buoyancy.

The escape of gas from the space 80 will be understood to effect a reduction of pressure therein which will continue until the control means returns to a null state wherein the valves 52 are again seated around the ports 54*a*. Thus, as in descent, there is a controlled regulation of the diver's buoyancy.

The control means may be manually adjusted by rotation of the end cap 46 to set the buoyancy to a desired amount. If the end cap 46 is rotated it will, by virtue of its screw-thread engagement with the housing 42, effect bodily movement of the capsule 50, which movement will be towards either the left or the right according to the direction of rotation of the end cap 46. Rotation of the end cap to cause a leftward movement of the capsule 50 will effect opening movement between the side 50*b* and the slider 54 and thus, as described hereinbefore with reference to Figure 5, the trigger 70 will be actuated to admit pressurised gas and increase buoyancy. Conversely, rotation in the opposite sense will effect relative closing movement of the side 50*b* and slider 54, leading to a reduction in buoyancy. In this way, by rotation of the end cap 46, a diver can manually vary his buoyancy over a range from negative to positive. Thus the diver can, for instance, adjust for negative buoyancy to ease descent, then reset to neutral buoyancy at his operating depth, and finally readjust to positive buoyancy for ascent at a controlled rate. It will be noted that the control means can be adjusted to compensate for the weight of loads such as tools or items recovered during a dive, to compensate for increase of buoyancy as the diver's breathing medium is consumed, and

also, which may be particularly important, to give neutral buoyancy at a decompression stop.

The end cap 46 should, of course, be so formed as to enable the diver easily to rotate it, for instance with heavy knurling around the rim 86*a* and a fairly coarse-threaded engagement with the housing 42. Also, it must be so arranged that its rotation does not strain the necessarily precise components of the tilt valve arrangement. The housing 42 may be some 2 in. in diameter and may be held by the harness at any easily reached point. A quick-release clasp on the harness and the nature of coupling 78 (Figure 4) enable the apparatus to be jettisoned rapidly in an emergency.

Certain other features of the aforedescribed control means may now be brought out. Firstly, the variable displacement bag is resilient so that it will contract to a state of reduced buoyancy when the ports 54a are opened and thus the pressure in the space 80 must necessarily be somewhat greater than the ambient pressure when the control means stabilises in its null state. The spring 58 can be seen to compensate for this difference between the pressures on opposed faces of the slider 54, which difference is representative of the resilience of the variable displacement bag. Ideally, then, the rate of the spring 58 is matched to the resilience of the bag; that is, the spring 58 compresses in linear relation to the expansion of the bag.

Secondly, it will be recalled from Figure 1 that the rate of change of volume of a gas with depth is markedly less at greater depths and, without some form of compensation, this would lead to a reduction in sensitivity of the control means at sch greater depths. However, it will be seen from Figure 6 that at depth, when the capsule 50 is well compressed, the leftward displacement of the pivot 68 relative to the trigger 70 means that any actuation of the trigger 70 will be by a part of the arm 66 which is comparatively far from the pivot 68 and which will thus have a greater degree of movement for the same change in the spacing between the side 50*b* and the slider 54. Thus there is an increased response of the tilt valve arrangement which tends to counteract the reduced response of the capsule 50. It should be remarked, though, that this provision is not essential, particularly since the apparatus is likely to be most beneficial in depths down to about 10m. where the change of buoyancy with depth is most rapid and where, accordingly change of buoyancy with depth is most rapid and where, accordingly, the capsule has a rapid response. It may also be possible to profile the arm 66 to give a desired response.

Thirdly, it should be understood that the state of the control means as shown in Figures 5 and 6 is greatly exaggerated. In practice, of course, such sudden changes as those depicted are hardly likely to occur, and there will be a progressive regulation of buoyancy. It will be seen that, by matching the expansion/contraction behaviour of the variable displacement bag to the buoyancy characteristic of the diver's suit, such as that represented by curve 12 of Figure 1, the diver's buoyancy can be regulated.

Figures 7 and 8 illustrate two alternative forms of control means which will now be discussed very briefly. Reffering firstly to Figure 7, the housing 88 and slider 90 are shown to be of substantially the same form as the housing 42 and slider 54 of the aforedescribed control means. However, the capsule 50 of the latter is replaced by an air-containing drum comprising a cylinder element 92 and a piston element 94. The cylinder element 92 fits within the housing 88 in such a way as to permit passage therebetween of water at ambient pressure into the space 96 within the housing 88. Extending from the piston element 94 and through the slider 90 is a pipe 98 having sealed sliding engagement with the slider 90. A flexible gas line 100 leads from a connector 102 on the housing 88 to a manifold 104 carried on the slider 90 about the pipe 98. The slider 90 closes off a space 106 which is open, by way of a port 107, to a variable displacement chamber, not shown, and is biased towards the right by a spring 108.

If the control means of Figure 7 is subjected to increased ambient pressure, as in descent, the piston element 94 and slider 90 are forced apart to bring a conduit 110 into register with an inlet port 112 in the manifold 104, thus causing the entry of pressurised gas through the line 100 and an increase in displacement, and buoyancy, of the chamber. Conversely, reduced ambient pressure will cause alignment of the conduit 110 with an outlet port 114 in the manifold 104, leading to a venting of gas from the chamber. In each case, there will be understood to be a control action, and thus buoyancy will be regulated. It will also be understood that end cap 116 can be rotated to effect setting of buoyancy to a required amount.

The use of a flexible connection such as the line 100 of Figure 7 may be avoided by the arrangement of Figure 8. In this alternative arrangement the pipe 118 extending from the piston element 120 is formed with a bore 122 which mates with a spigot 124. The spigot 124 is formed with first and second passages 126 and 128. The first passage 126 extends through a limb 130 of the spigot 124 and the limb 130 extends through the housing 132 to provide an inlet for pressurised gas. A duct 134 extends from

the space 136 through the slider 138 and slider-mounted port 140. For simplicity in illustration, no spring equivalent to the spring 108 of Figure 7 is shown in Figure 8, but it will be appreciated that such is necessary to urge the slider 138 rightwards.

If the piston element 120 moves, under the influence of increased ambient pressure, away from the slider 138, an inlet port 142 in the pipe 118 effects communication between said first passage 126 and the duct 134. Thus pressurised gas is delivered to the space 136 and thence, by way of a port 144, to increase the displacement of variable displacement chamber, not shown. If there is a reduction of ambient pressure, the piston element 120 moves towards the slider 138 to register an outlet port 146 in the pipe 118 with a port 148 in the port 140, thus to allow the escape of pressurised gas through the second passage 128. In this way the chamber means contracts in reducing ambient pressure. It will be appreciated that, as with the control means hereinbefore described with reference to Figures 3 to 7, the control means of Figure 8 also effects controlled regulation of buoyancy. The chamber of the invention may have sufficient variation of displacement to afford buoyancy over the range 0 - 6 kgf, which would allow buoyancy regulation for a medium-sized male diver, clad in a wetsuit of 6mm thickness neoprene, down to a depth of about 30m. (The surface buoyancy of his suit would be about 8 kgf, and at a depth of 30 m. this would have dropped to about 2 kgf, requiring the maximum available contribution of 6kgf from the chamber if buoyancy is to be regulated.) This depth can be seen to cover most sporting and many professional diving activities, and the buoyancy characteristic of Figure 1 shows that below this depth the rate of change of buoyancy with depth is in any case quite slow. Furthermore, the diver's comsumption of his breathing medium will, at such depths, rapidly counteract any negative buoyancy he may have, a typical air-tank having a 2.5 kgf range of buoyancy.

A large diver having a particularly thick wetsuit, or a diver wearing another more buoyant suit, may require a greater range of buoyancy regulation than the 0 - 6 kgf suggested, although even in such cases the suggested range should be ample in the initial 10 m. from the surface, where buoyancy changes are most marked.

The sensor means such as the capsule 50 of Figure 3 will be understood to mimic the response of a diver's suit to varying ambient pressure; that is, it will respond in substantially the same way as the suit. Thus, instead of such a capsule, a block of the suit material (usually neoprene) may be used. From experiments it has been found that a sandwich construction comprising several suit thicknesses alternating with aluminium discs (to counter lateral forces and thus avoid errors due to the effect of Poisson's ratio) is particularly convenient.

It will be appreciated that the invention is not limited to the embodiments particularly described hereinbefore, nor necessarily to the applications set forth. Various modifications and additions will be apparent to those skilled in the art.

WHAT I CLAIM IS:-

1. Apparatus for regulating buoyancy of an underwater diver in relation to ambient pressure in the water and comprising a supply of gas at a pressure which in use is above the maximum ambient pressure, a resilient chamber, for gas, of volume variable (at constant ambient pressure) linearly with pressure in the chamber and control means for controlling the volume of gas within the chamber thus to vary its displacement in the water, wherein the control means comprises:

a housing having a first port connected to said supply of gas, a second port connected to said chamber and a third port open to the water;

valve means arranged within the housing to cooperate with said ports, which valve means has a null position wherein all the ports are shut off from one another by the valve means, a first position wherein the first and second ports are in communication, and a second position wherein the second and third ports are in communication;

a transducer within the housing, which transducer is responsive to ambient pressure and operative to move the valve means from the null position to the first position when ambient pressure increases and from the null position to the second position when ambient pressure decreases;

and spring means to urge the valve means towards the null position.

2. Apparatus as claimed in Claim 1 wherein said control means is manually adjustable to set the buoyancy of the apparatus to a desired amount.

3. Apparatus as claimed in Claim 1 or Claim 2 wherein said chamber comprises a piston and cylinder.

4. Apparatus as claimed in Claim 1 or Claim 2 wherein said chamber comprises a resiliently deformable bag.

5. Apparatus as claimed in Claim 4 wherein said bag has a number of compartments.

6. Apparatus as claimed in any preceding claim wherein said gas is the diver's breathing medium.

7. Apparatus as claimed in any preceding claim wherein the chamber is included in a lifejacket.

8. Apparatus as claimed in Claim 7 including means manually operable to fill

and/or empty said lifejacket.

9. Apparatus as claimed in any preceding claim wherein the means for securing the apparatus to the body includes said chamber means.

10. Apparatus as claimed in any preceding claim wherein the control means is arranged to compensate for variation in response of the transducer with depth.

11. Apparatus as claimed in any preceding claim wherein said transducer comprises a gas-filled capsule.

12. Apparatus as claimed in any of Claims 1 to 10 wherein said transducer comprises a block of neoprene.

13. Apparatus for regulating buoyancy of an underwater diver substantially as hereinbefore described with reference to, and as shown in, Figures 2 to 6 of the accompanying drawings.

14. Apparatus for regulating buoyancy of an underwater diver substantially as hereinbefore described with reference to and as shown in Figures 2 and 7 of the accompanying drawings.

15. Apparatus for regulating buoyancy of an underwater diver substantially as hereinbefore described with reference to and as shown in Figures 2 and 8 of the accompanying drawings.

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Agent for the Applicant

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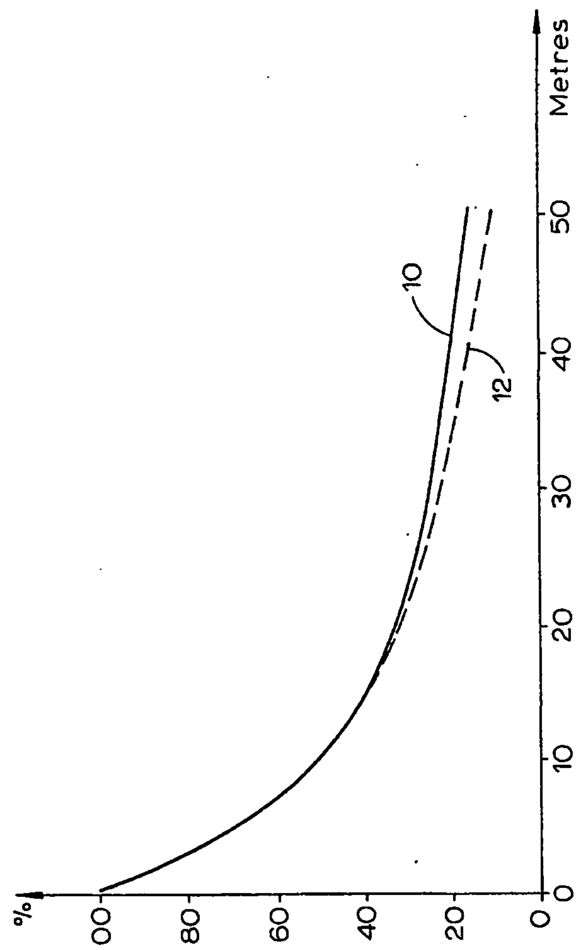

Fig. 1

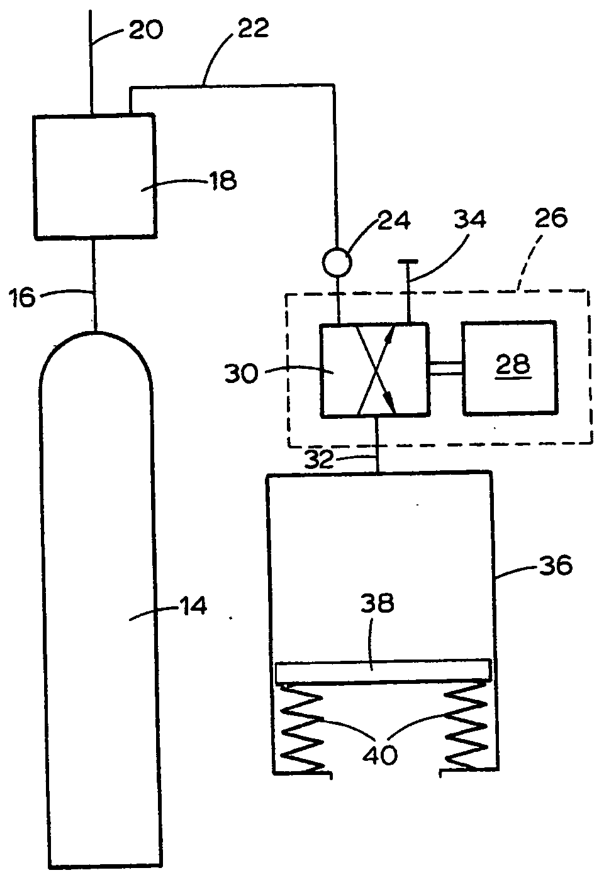

Fig. 2

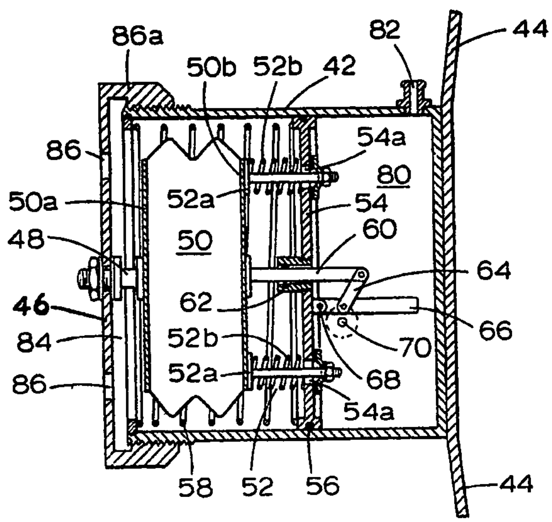
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Fig. 3

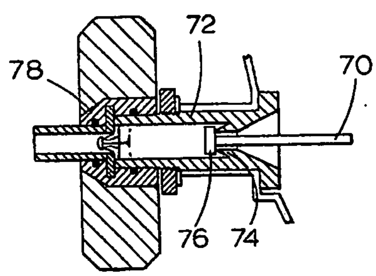
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Fig. 4

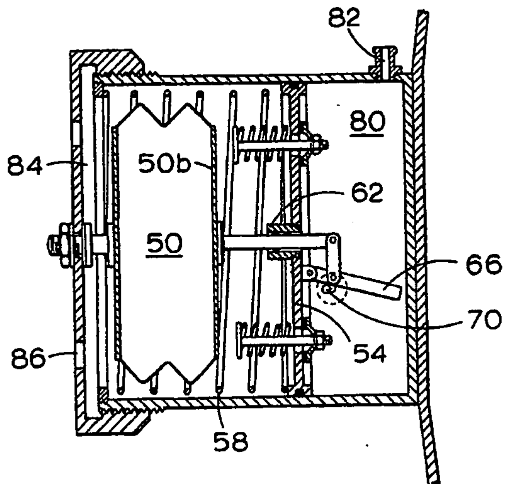
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Fig. 5

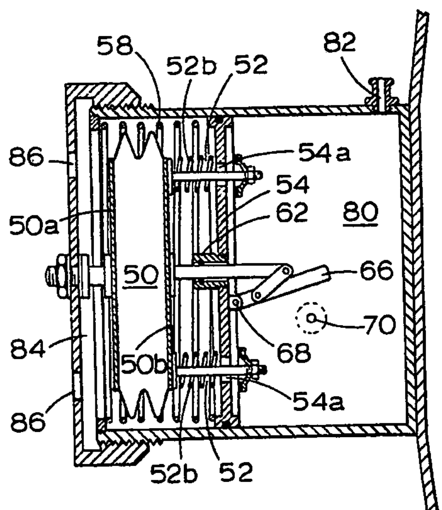
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Fig. 6

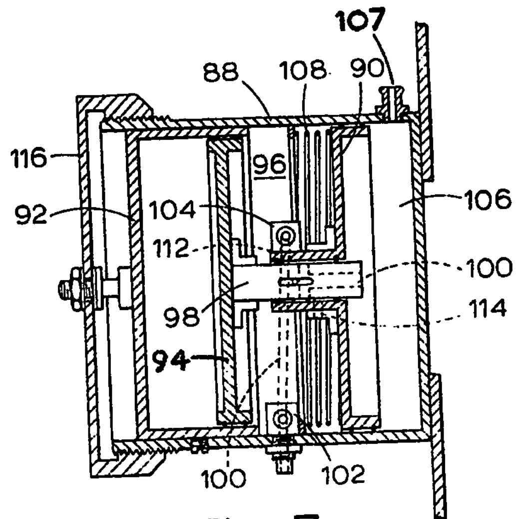
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Fig. 7

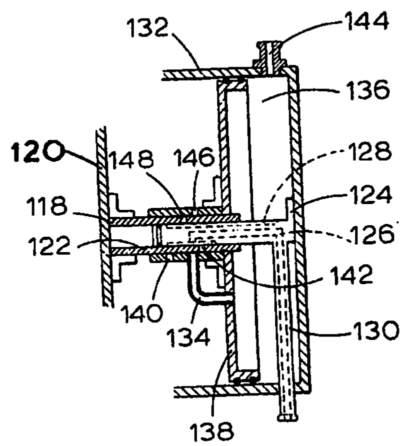
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Fig. 8